第三次作业

- 分析环境

OS	Arch
Microsoft Windows 10	Intel64

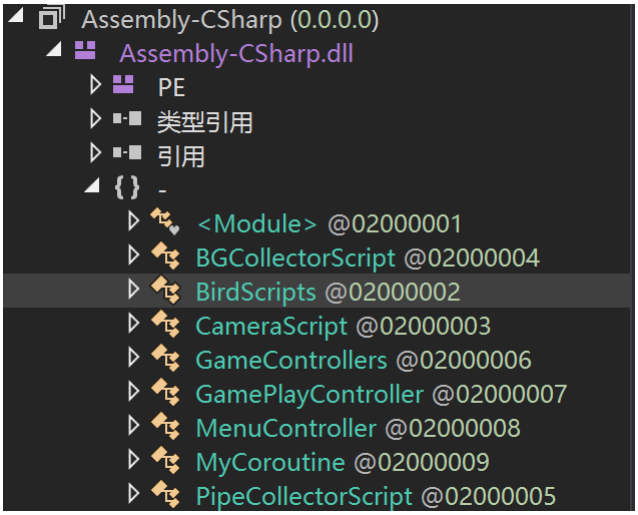
- 使用工具

Tools	Version
Detect It Easy	v3.01
DnSpy	v6.1.8
Cheat Engine	v7.5
SharpMonoInjector.gui	v2.3
MelonLoader.Installer	v3.0.8
Microsoft Visual Studio 2022	

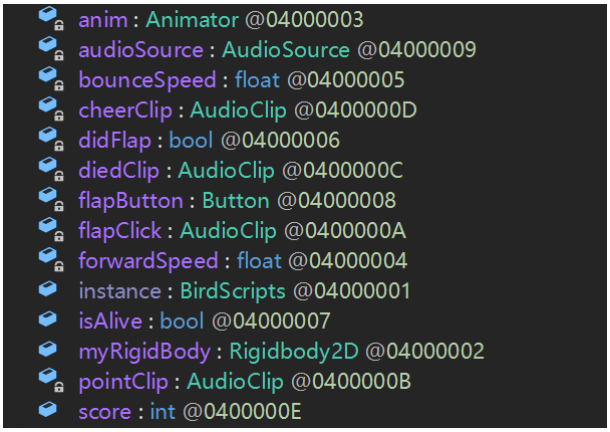
1. 静态分析游戏关键逻辑

用`Detect It Easy`检查`FlappyBird.exe`，没有任何保护层。再结合视频课程中介绍，该游戏由`Unity-Mono`开发，可以使用`DnSpy`直接进行反编译攻击获取源码。

由于`Managed/Assembly-CSharp.dll`通常存放该游戏的关键类数据和关键逻辑，故直接用`DnSpy`对该文件进行反编译：如下图，可以看到`BirdScripts` / `GameControllers` / `PipeCollectorScrpt`等与游戏内容密切相关的类名。



查看源码，能推测`BirdScripts`是控制小鸟对象的类，其中有关键属性`bounceSpeed`控制跳跃高度、`forwardSpeed`控制前进速度、`isAlice`控制是否存活和`score`控制当前得分。



而`OnCollisionEnter2D()`方法就明显是小鸟碰撞死亡后显示游戏结束画面的函数，以及小鸟在存活状态下触碰`Flag`后播放胜利庆祝画面表示成功通关；`OnTriggerEnter2D()`方法则在小鸟翻过管道后加分并调用`GamePlayController.instance.setScore()`重新设置画面中的分数。

```
// BirdScripts
// Token: 0x06000008 RID: 8 RVA: 0x00002270 File Offset: 0x00000470
private void OnCollisionEnter2D(Collision2D target)
{
    if (target.gameObject.tag == "Pipe" || target.gameObject.tag == "Ground" || target.gameObject.tag == "Enemy")
    {
        if (this.isAlive)
        {
            this.isAlive = false;
            this.anim.SetTrigger("BirdDied");
            this.audioSource.PlayOneShot(this.diedClip);
            GamePlayController.instance.playerDiedShowScore(this.score);
        }
    }
    else if (target.gameObject.tag == "Flag" && this.isAlive)
    {
        this.isAlive = false;
        this.audioSource.PlayOneShot(this.cheerClip);
        GamePlayController.instance.finishGame();
    }
}
```

```
private void OnTriggerEnter2D(Collider2D target)
{
    if (target.tag == "PipeHolder")
    {
        this.audioSource.PlayOneShot(this.pointClip);
        this.score++;
        GamePlayController.instance.setScore(this.score);
    }
}
```

`FixedUpdate`则有点特殊，猜测是用于更新游戏画面、游戏音乐，使存活的小鸟保持前进并在响应`Flap`振翅事件后保持y方向上的朝向角度（就是上升时头朝上下降时头复原）。

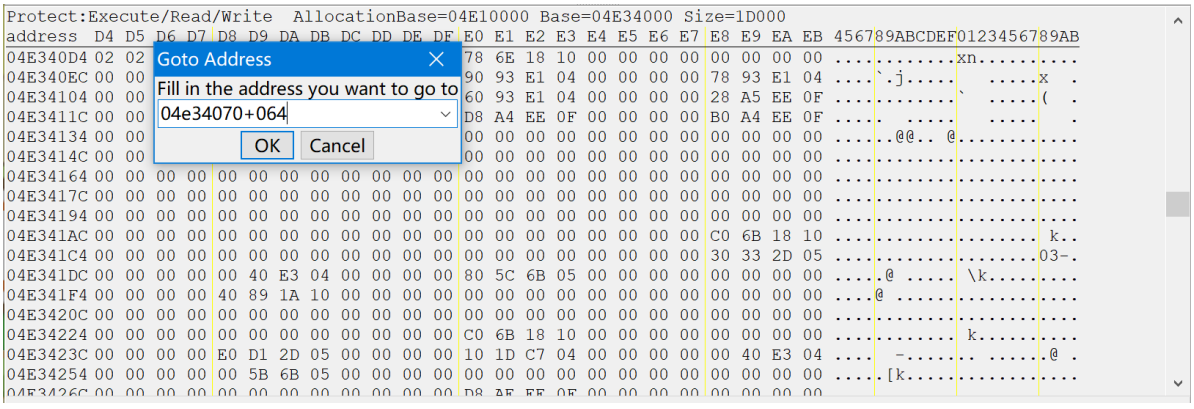
```
private void FixedUpdate()
{
    if (this.isAlive)
    {
        Vector3 position = base.transform.position;
        position.x += this.forwardSpeed * Time.deltaTime;
        base.transform.position = position;
        if (this.didFlap)
        {
            this.didFlap = false;
            this.myRigidBody.velocity = new Vector2(0f, this.bounceSpeed);
            this.audioSource.PlayOneShot(this.flapClick);
            this.anim.SetTrigger("Flap");
        }
        if (this.myRigidBody.velocity.y >= 0f)
        {
            base.transform.rotation = Quaternion.Euler(0f, 0f, 0f);
        }
        else
        {
            float z = Mathf.Lerp(0f, -70f, -this.myRigidBody.velocity.y / 7f);
            base.transform.rotation = Quaternion.Euler(0f, 0f, z);
        }
    }
}
```

2. 游戏破解实战

2.1 CheartEngine附加动态修改

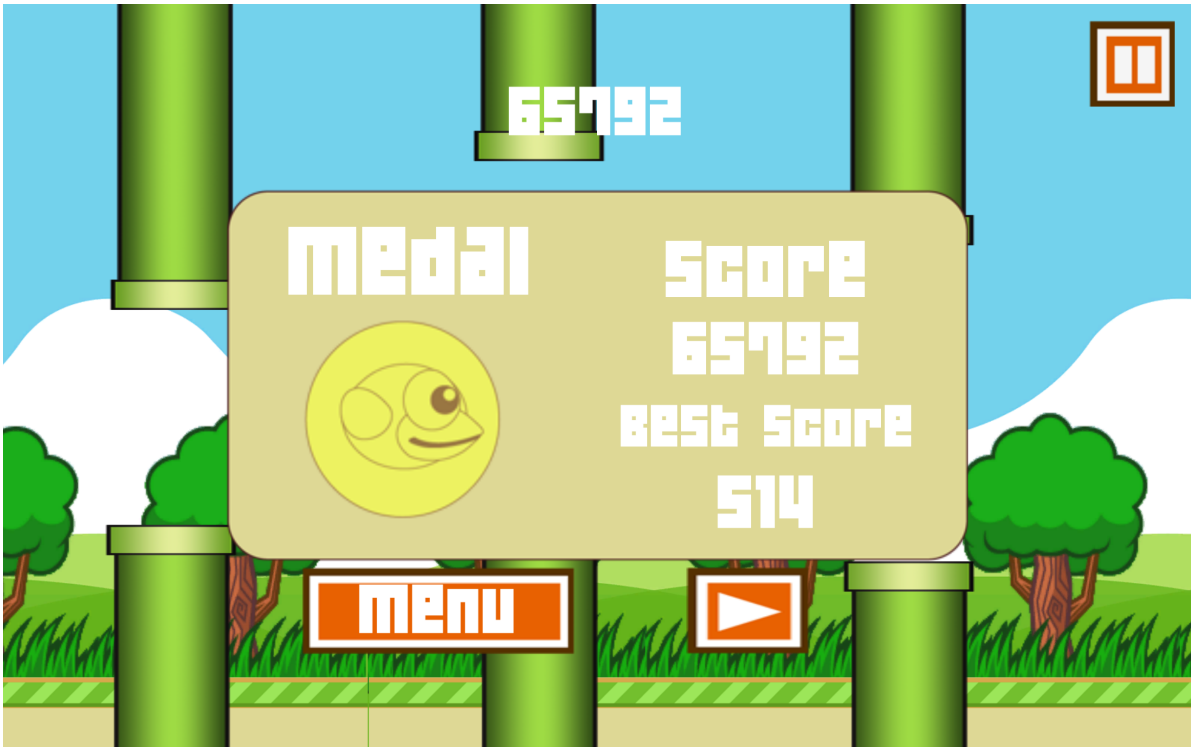
2.1.1 直接修改内存

使用`CheatEngine`的`Mono`插件，直接找到`Assembly-CSharp`镜像中`BirdScripts`类的基地址和成员的偏移地址。其中`score`的地址为`0x04e34070+0x64`，直接访问该块内存，修改为`0xFFFF`



Protect:Execute/Read				
address	D4	D5	D6	D7
04E340D4	FF	FF	00	00
04E340EC	00	00	00	00

在游戏窗口中可以看到，当前的分数已经加上了`0xFFFF`，已经变成了一个巨大的数字

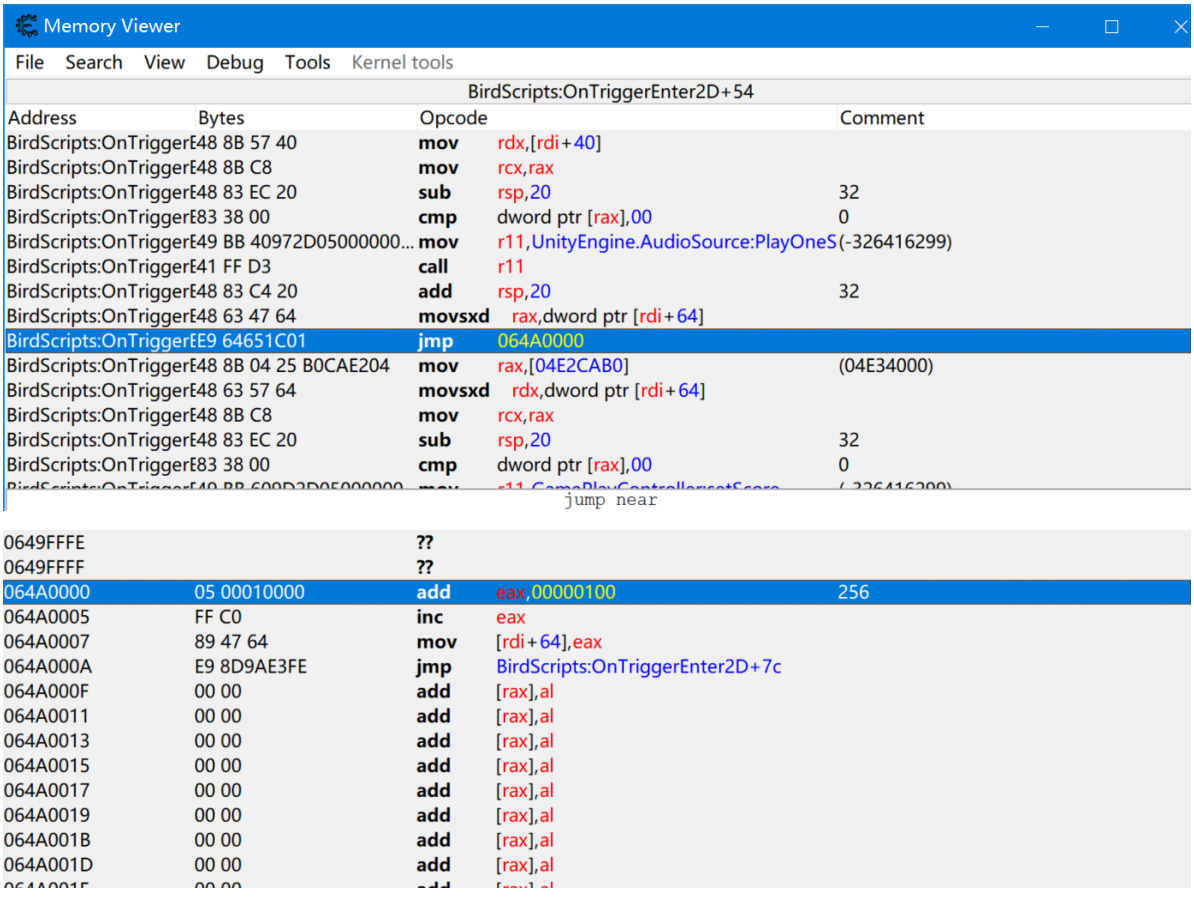


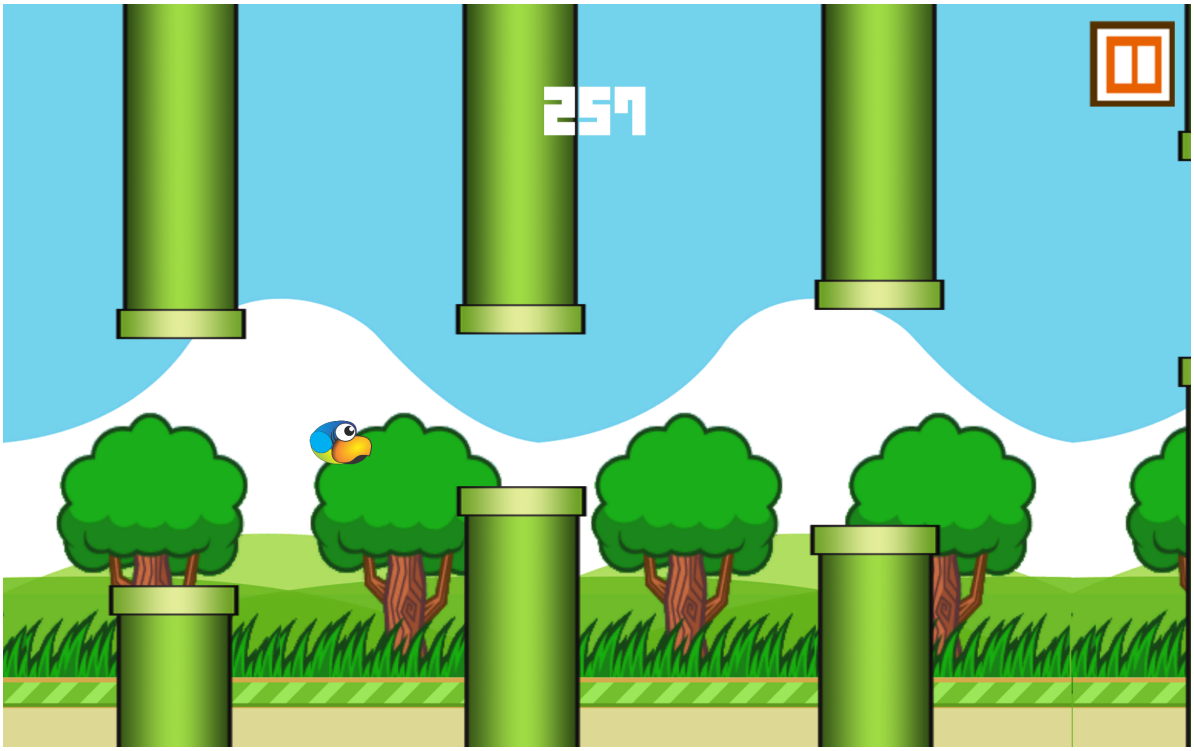
2.1.2 修改加分逻辑

尝试修改`OnTriggerEnter2D`的逻辑，原汇编代码如下，其中`inc eax`就是每次翻越管道后的加分逻辑：

```
inc eax
mov [rdi+64],eax
```

但我使用工具栏中的`Auto Assembly`功能编写了注入代码，通过跳转到`0x064A0000`进行额外的加分。这样小鸟每次翻越管道都会加0x101（257）分。





2.1.3 修改碰撞逻辑

尝试修改 `OnCollisionEnter2D` 的逻辑，关注 `get_gameObject` 和 `get_tag` 后的几次比较+跳转：

BirdScripts:OnCollisionEnter2D+9d

Address	Bytes	Opcode		Comment
BirdScripts:OnCollisior	48 83 C4 20	**add**	rsp,20	32
BirdScripts:OnCollisior	48 8B C8	**mov**	rcx,rax	
BirdScripts:OnCollisior	BA E8C8EE0F	**mov**	edx,0FEEC8E8	(04C68FC8)
BirdScripts:OnCollisior	48 83 EC 20	**sub**	rsp,20	32
BirdScripts:OnCollisior	49 BB D02D2805000000...	**mov**	r11,System.String:op_Equality	(-326416299)
BirdScripts:OnCollisior	41 FF D3	**call**	r11	
BirdScripts:OnCollisior	48 83 C4 20	**add**	rsp,20	32
BirdScripts:OnCollisior	85 C0	**test**	eax,eax	
BirdScripts:OnCollisior	0F85 5B000000	**jne**	BirdScripts:OnCollisionEnter2D+121	
BirdScripts:OnCollisior	48 8B CE	**mov**	rcx,rsi	
BirdScripts:OnCollisior	48 83 EC 20	**sub**	rsp,20	32
BirdScripts:OnCollisior	83 3E 00	**cmp**	dword ptr [rsi],00	0
BirdScripts:OnCollisior	49 BB 25B02D05000000...	**mov**	r11,00000000052DB025	(232)

BirdScripts:OnCollisionEnter2D+121

Address	Bytes	Opcode		Comment
BirdScripts:OnCollisior	0FB6 47 61	**movzx**	eax,byte ptr [rdi+61]	
BirdScripts:OnCollisior	85 C0	**test**	eax,eax	
BirdScripts:OnCollisior	0F84 28010000	**je**	BirdScripts:OnCollisionEnter2D+255	
BirdScripts:OnCollisior	C6 47 61 00	**mov**	byte ptr [rdi+61],00	0
BirdScripts:OnCollisior	48 8B 47 20	**mov**	rax,[rdi+20]	
BirdScripts:OnCollisior	48 8B C8	**mov**	rcx,rax	
BirdScripts:OnCollisior	BA 10EEEE0F	**mov**	edx,0FEEEE10	(04C68FC8)
BirdScripts:OnCollisior	48 83 EC 20	**sub**	rsp,20	32
BirdScripts:OnCollisior	83 38 00	**cmp**	dword ptr [rax],00	0
BirdScripts:OnCollisior	49 BB D0982D05000000...	**mov**	r11,UnityEngine.Animator:SetTrigger	(-326416299)
BirdScripts:OnCollisior	41 FF D3	**call**	r11	
BirdScripts:OnCollisior	48 83 C4 20	**add**	rsp,20	32
BirdScripts:OnCollisior	48 8B 47 30	**mov**	rax,[rdi+30]	

在每次调用 `op_Equality` 之前都会对edx进行赋值，猜测这些地址是待比较的字符串的地址，跳转过去发现确实符合猜测。总结，它们分别是 `0xC898` 对应 `Flag`、`0xC8C0` 对应 `Enemy`、`0xC8E8` 对应 `Ground`、`0xCF50` 对应 `Pipe`。

```
Protect:Execute/Read/Write  AllocationBase=0FEB0000 Base=0FEEC000 Size=5000
address  E8 E9 EA EB EC ED EE EF F0 F1 F2 F3 F4 F5 F6 F7 F8 F9 FA FB FC FD FE FF 89ABCDEF0123456789ABCDEF
0FEEC8E8 C8 8F C6 04 00 00 00 00 00 00 00 00 00 00 00 00 06 00 00 00 47 00 72 00    ................G.r.
0FEEC900 6F 00 75 00 6E 00 64 00 00 00 00 00 00 00 00 00 C8 8F C6 04 00 00 00 00 o.u.n.d.........    .....
0FEEC918 00 00 00 00 00 00 00 00 06 00 00 00 43 00 61 00 6E 00 63 00 65 00 6C 00 ............C.a.n.c.e.l.
0FEEC930 00 00 00 00 00 00 00 00 C8 8F C6 04 00 00 00 00 00 00 00 00 00 00 00 00 ........    ............
0FEEC948 05 00 00 00 4D 00 65 00 64 00 61 00 6C 00 00 00 00 00 00 00 00 00 00 00 ....M.e.d.a.l...........
0FEEC960 C8 8F C6 04 00 00 00 00 00 00 00 00 00 00 00 00 04 00 00 00 4D 00 65 00    ................M.e.
0FEEC978 6E 00 75 00 00 00 65 00 64 00 00 00 00 00 00 00 C8 8F C6 04 00 00 00 00 n.u...e.d.......    .....
0FEEC990 00 00 00 00 00 00 00 00 07 00 00 00 50 00 72 00 65 00 73 00 73 00 65 00 ............P.r.e.s.s.e.
0FEEC9A8 64 00 00 00 00 00 00 00 C8 8F C6 04 00 00 00 00 00 00 00 00 00 00 00 00 d.......    ............
0FEEC9C0 06 00 00 00 4E 00 6F 00 72 00 6D 00 61 00 6C 00 00 00 00 00 00 00 00 00 ....N.o.r.m.a.l.........
0FEEC9D8 C8 8F C6 04 00 00 00 00 00 00 00 00 00 00 00 00 07 00 00 00 50 00 72 00    ................P.r.
0FEEC9F0 65 00 73 00 73 00 65 00 64 00 00 00 00 00 00 00 C8 8F C6 04 00 00 00 00 e.s.s.e.d.......    .....
0FEECA08 00 00 00 00 00 00 00 00 06 00 00 00 4E 00 6F 00 72 00 6D 00 61 00 6C 00 ............N.o.r.m.a.l.
0FEECA20 00 00 00 00 00 00 00 00 C8 8F C6 04 00 00 00 00 00 00 00 00 00 00 00 00 ........    ............
0FEECA38 07 00 00 00 50 00 72 00 65 00 73 00 73 00 65 00 64 00 00 00 00 00 00 00 ....P.r.e.s.s.e.d.......
0FEECA50 C8 8F C6 04 00 00 00 00 00 00 00 00 00 00 00 00 06 00 00 00 4E 00 6F 00    ................N.o.
0FEECA68 72 00 6D 00 61 00 6C 00 00 00 00 00 00 00 00 00 C8 8F C6 04 00 00 00 00 r.m.a.l.........    .....
0FEECA80 00 00 00 00 00 00 00 00 07 00 00 00 50 00 72 00 65 00 73 00 73 00 65 00            P.r.e.s.s.e
```

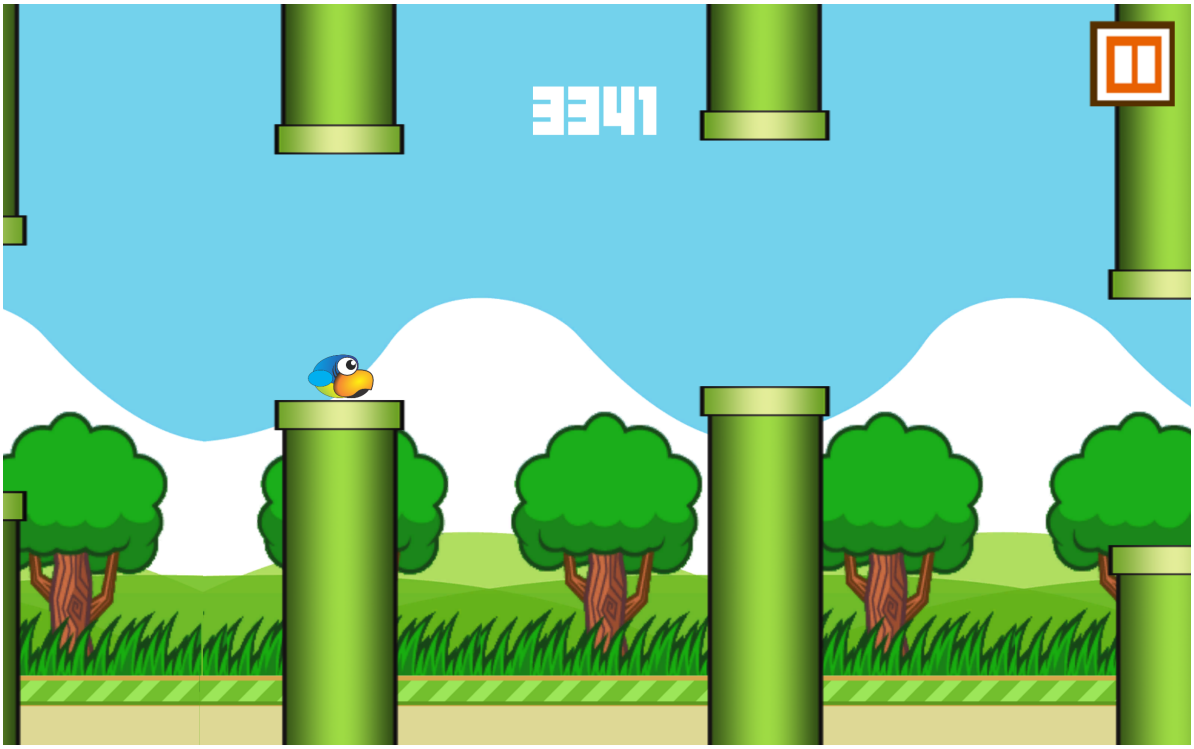
知道了上述标签便更容易定位判断逻辑，易知偏移地址为`0x121`处的代码逻辑可能是存活判断，因此把这里的`je`改为`jmp`便可以patch掉死亡逻辑。

> 这里的**[rdi+61]**是典型的结构体属性访问，可以轻松判断这是对this->isAlive属性的访问指令。

BirdScripts:OnCollisionEnter2D+121

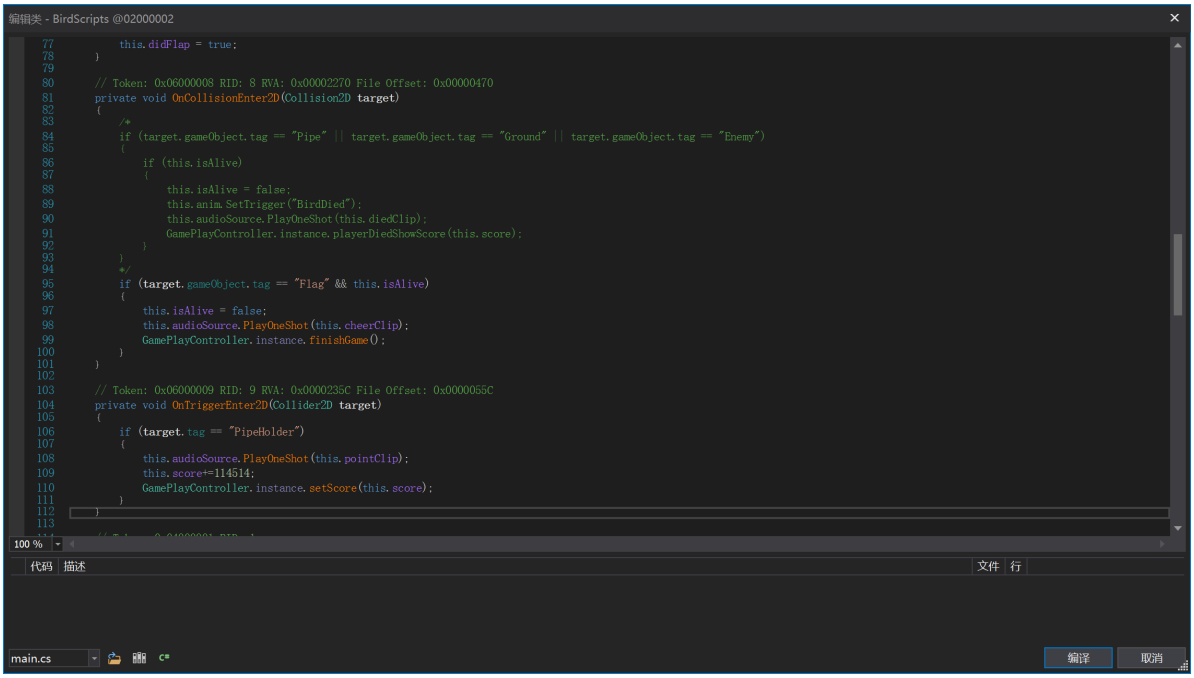
Address	Bytes	Opcode		Comment
BirdScripts:OnCollisior	0FB6 47 61	**movzx**	eax,byte ptr [rdi+61]	
BirdScripts:OnCollisior	85 C0	**test**	eax,eax	
BirdScripts:OnCollisior	E9 29010000	**jmp**	BirdScripts:OnCollisionEnter2D+255	
BirdScripts:OnCollisior	90	**nop**		
BirdScripts:OnCollisior	C6 47 61 00	**mov**	byte ptr [rdi+61],00	0
BirdScripts:OnCollisior	48 8B 47 20	**mov**	rax,[rdi+20]	
BirdScripts:OnCollisior	48 8B C8	**mov**	rcx,rax	
BirdScripts:OnCollisior	BA 10EEEE0F	**mov**	edx,0FEEEE10	(04C68FC8)
BirdScripts:OnCollisior	48 83 EC 20	**sub**	rsp,20	32
BirdScripts:OnCollisior	83 38 00	**cmp**	dword ptr [rax],00	0
BirdScripts:OnCollisior	49 BB D0982D05000000...	**mov**	r11,UnityEngine.Animator:SetTrigger	(-326416299)
BirdScripts:OnCollisior	41 FF D3	**call**	r11	
BirdScripts:OnCollisior	48 83 C4 20	**add**	rsp,20	32

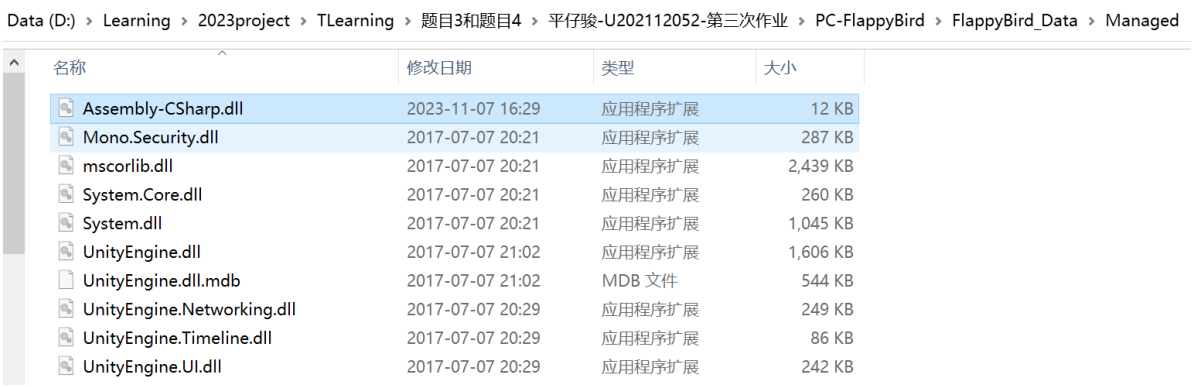
修改效果如下，小鸟碰撞管道也不会触发游戏结束的事件。



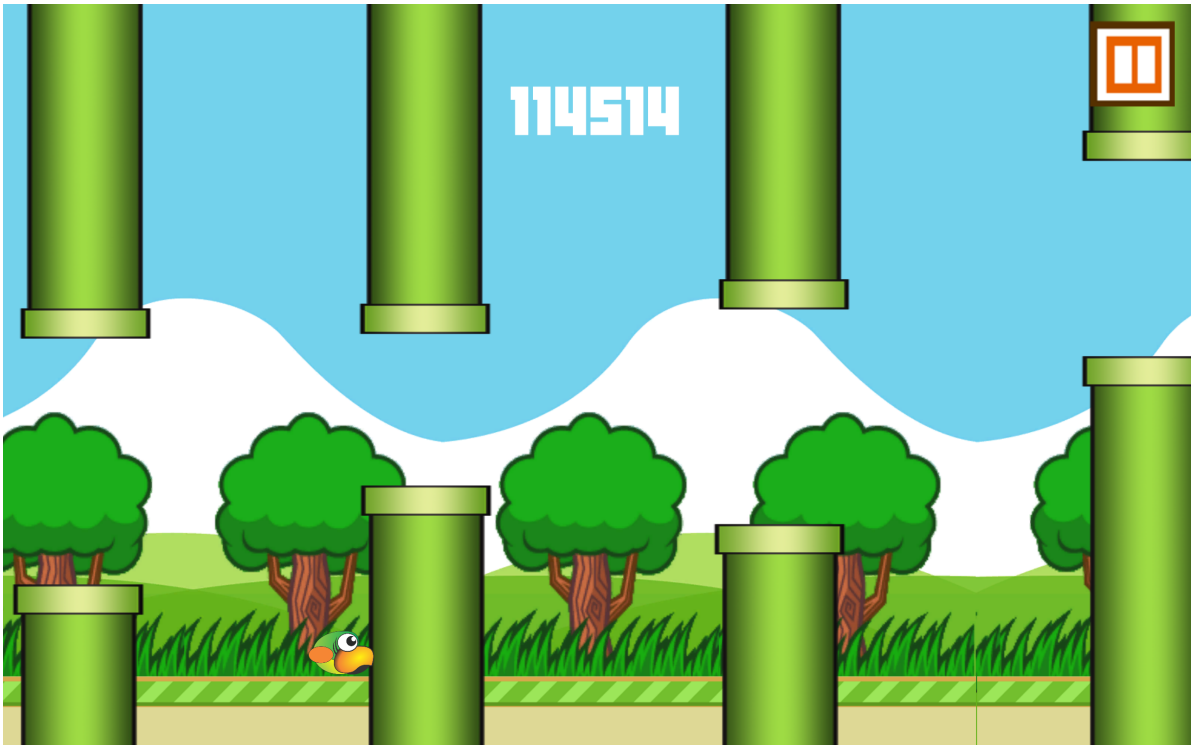
2.2 DnSpy重新编译库文件Assembly-CSharp.dll

如下图重新编辑Assembly-CSharp.dll中的`BirdScripts`类，将小鸟的碰撞死亡逻辑和触发加分逻辑进行的修改，并加以重新编译。





结合上图和下图，可以看出，在替换了新的库文件后，游戏的逻辑已经被我永久修改。（在后面的实验中会将原库文件替换回来，不用担心游戏的完整性。）



2.3 SharpMonoInjector实现插件注入

使用VS2022编写插件程序集，使用`SharpMonoInjector`获取Mono导出接口注入程序集。

先编写加载器`Loader`，使注入程序集时能够自动加载一个新的游戏对象，并将所编写的`Cheat`类作为组件挂载在游戏对象下面。

```
public class Loader
{
    static UnityEngine.GameObject gameObject;
    public static void Load()
    {
        gameObject = new UnityEngine.GameObject();
        gameObject.AddComponent<Cheat>(); // 挂载组件
        UnityEngine.Object.DontDestroyOnLoad(gameObject);
    }
    public static void Unload()
    {
        UnityEngine.Object.Destroy(gameObject);
    }
}
```

在编写插件的主要逻辑，先准备好对私有字段、属性、方法的操作函数，主要利用C#的反射特性，使得我们能通过已知的实例对象获取类型（Type）信息，从而获取其私有成员并进行读取、赋值、调用等。

```
        // 1. 获取私有字段
        public static T GetPrivateField<T>(this object instance, string
fieldname)
        {
            BindingFlags flag = BindingFlags.Instance |
BindingFlags.NonPublic;
            Type type = instance.GetType();
```

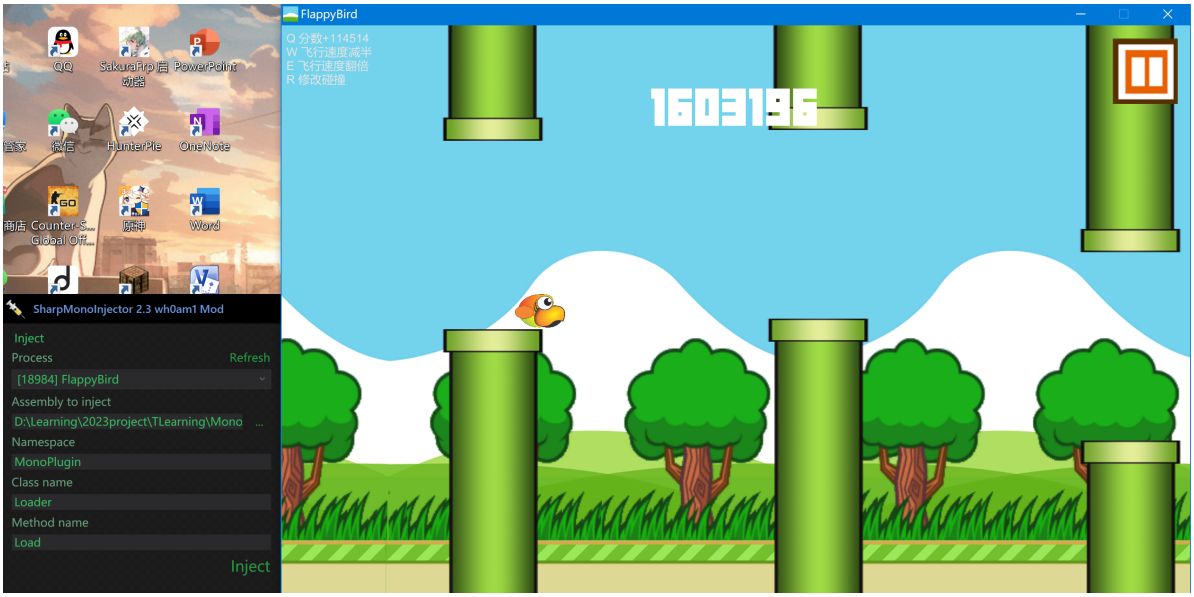
```
            FieldInfo field = type.GetField(fieldname, flag);
            return (T)field.GetValue(instance);
        }
        // 2. 获取私有属性
        public static T GetPrivateProperty<T>(this object instance, string
propertyname)
        {
            BindingFlags flag = BindingFlags.Instance |
BindingFlags.NonPublic;
            Type type = instance.GetType();
            PropertyInfo field = type.GetProperty(propertyname, flag);
            return (T)field.GetValue(instance, null);
        }
        // 3. 设置私有成员
        public static void SetPrivateField(this object instance, string
fieldname, object value)
        {
            BindingFlags flag = BindingFlags.Instance |
BindingFlags.NonPublic;
            Type type = instance.GetType();
            FieldInfo field = type.GetField(fieldname, flag);
            field.SetValue(instance, value);
        }
        // 4. 设置私有属性
        public static void SetPrivateProperty(this object instance, string
propertyname, object value)
        {
            BindingFlags flag = BindingFlags.Instance |
BindingFlags.NonPublic;
            Type type = instance.GetType();
            PropertyInfo field = type.GetProperty(propertyname, flag);
            field.SetValue(instance, value, null);
        }
        // 5. 调用私有方法
        public static T CallPrivateMethod<T>(this object instance, string
name, params object[] param)
        {
            BindingFlags flag = BindingFlags.Instance |
BindingFlags.NonPublic;
            Type type = instance.GetType();
            MethodInfo method = type.GetMethod(name, flag);
            return (T)method.Invoke(instance, param);
        }
```

最后编写GUI端显示和外挂逻辑，利用前面已经设计好的操作方法，使用 `FindWithTag()` 方法找到控制分数、速度、碰撞逻辑的实例对象，进行逻辑修改实现外挂。注意**每次修改分数并不代表界面中央显示的分数会即时改变**，必须要调用GamePlayController的实例设置新的分数。

```
// Q 键修改分数
if (Input.GetKeyDown(KeyCode.Q))
{
    var birdscript =
UnityEngine.GameObject.FindWithTag("player").GetComponent<BirdScripts>();
    var gamecontroller =
UnityEngine.GameObject.FindWithTag("player").GetComponent<GamePlayController
>();
    if (birdscript != null)
```

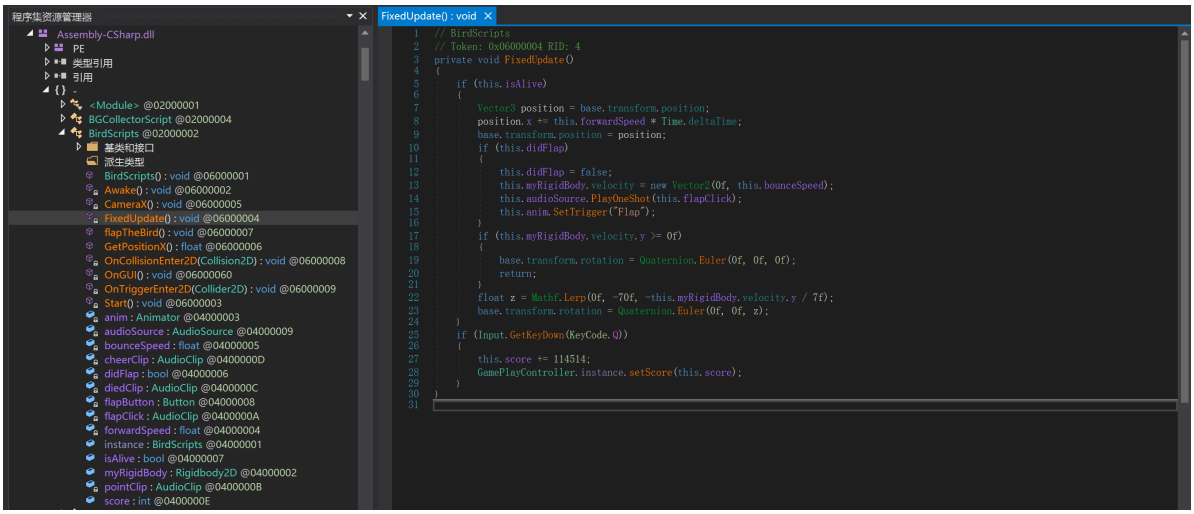
```
    {
        birdscript.score += 114514;
        // 这里需要调用GamePlayController的实例来执行setScore方法，刷新显示的分数
        gamecontroller.setScore(birdscript.score);
    }
}
// W 键修改前进速度(反射机制)
if (Input.GetKeyDown(KeyCode.W))
{
    var birdscript =
UnityEngine.GameObject.FindWithTag("player").GetComponent<BirdScripts>();
    Type type = birdscript.GetType();
    var forwardSpeed = OperaterPrivate.GetPrivateField<float>(birdscript,
"forwardSpeed");
    Debug.Log("forwardSpeed:" + forwardSpeed);
    forwardSpeed /= 2;
    OperaterPrivate.SetPrivateField(birdscript, "forwardSpeed",
forwardSpeed);
}
// E 键修改前进速度(反射机制)
if (Input.GetKeyDown(KeyCode.E))
{
    var birdscript =
UnityEngine.GameObject.FindWithTag("player").GetComponent<BirdScripts>();
    Type type = birdscript.GetType();
    var forwardSpeed = OperaterPrivate.GetPrivateField<float>(birdscript,
"forwardSpeed");
    Debug.Log("forwardSpeed:" + forwardSpeed);
    forwardSpeed *= 2;
    OperaterPrivate.SetPrivateField(birdscript, "forwardSpeed",
forwardSpeed);
}
// R 切换是否无碰撞
if (Input.GetKeyDown(KeyCode.R))
{
    var player = UnityEngine.GameObject.FindWithTag("Player");
    var birdscript = player.GetComponent<BirdScripts>();
    // 切换刚体碰撞逻辑的触发开关状态
    player.GetComponent<Collider2D>().isTrigger =
!player.GetComponent<Collider2D>().isTrigger;
}
```

使用`SharpMonoInjector 2.3`注入构建好的共享库文件，注入游戏进程后可以对游戏内容进行修改。



其实类似这种外挂实现也可以用`DnSpy`直接修改游戏的库文件实现（甚至只需要修改`BirdScripts.FixedUpdate`方法就可以实现即时新响应的外挂），最后在`BirdScripts`类中设置GUI的外挂键位提示，便可以实现与SharpMonoInjector注入完全相同的功能。下图是修改示例：

> 直接通过反编译修改源码显然是最轻松的“插件”方式，甚至不再需要**FindWithTag**可以直接访问一些对象



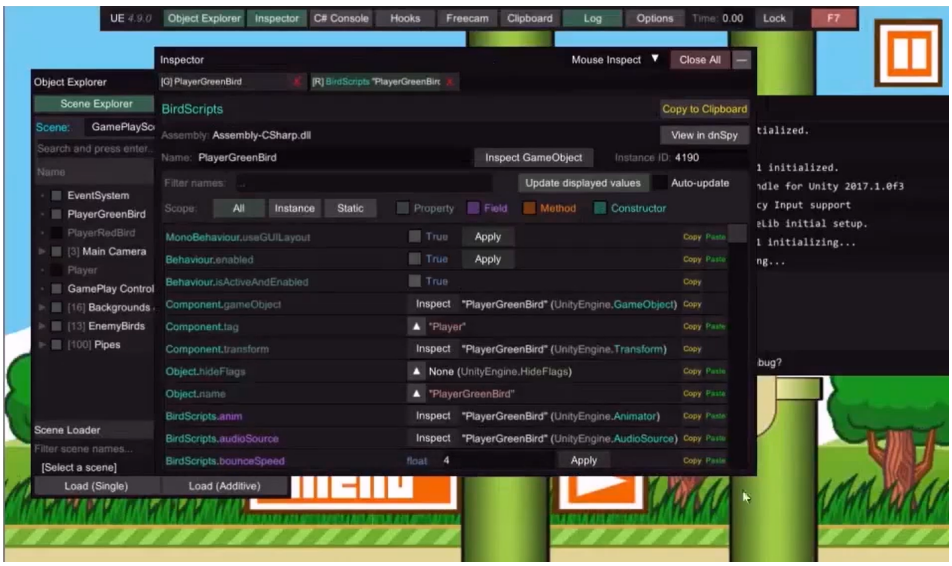
2.4 UnityExplorer插件给游戏打mod

本次用MelonLoader为FlappyBird安装mod环境，然后加入UnityExplorer插件。通过它的诸多功能对游戏进行内存修改、逻辑修改等。

(D:) › Learning › 2023project › TLearning › 题目3和题目4 › 平仔骏-U202112052-第三次作业 › PC-FlappyBird

名称	修改日期	类型	大小
FlappyBird_Data	2023-11-07 19:34	文件夹	
MelonLoader	2023-11-07 19:41	文件夹	
Mods	2023-11-07 19:41	文件夹	
Plugins	2023-11-07 19:41	文件夹	
UserData	2023-11-07 19:41	文件夹	
dobby.dll	2023-11-07 19:41	应用程序扩展	64 KB
FlappyBird.exe	2021-11-19 11:58	应用程序	22,888 KB
NOTICE.txt	2023-11-07 19:41	文本文档	1 KB
version.dll	2023-11-07 19:41	应用程序扩展	486 KB

根据之前的经验，可以直接使用`Inspector`菜单查看游戏中`BirdScrpts`类的各个成员信息，如果直接修改这里的数值，也可以实现之前已经实现的功能；同样的，也可以使用`Hook`菜单进行一些`JIT`汇编指令的patch，通过改变判断逻辑来实现包括但不限于”无敌“、”穿墙“、”额外加分“等效果。



修改分数之类的操作前面已经实现太多了，这里就不赘述，只展示一个关闭刚体触发碰撞后的“穿墙”效果。